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Solenoidal magnetic field influences the beam neutralization by a background plasma

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Solenoidal magnetic field influences the beam neutralization by a background plasma

An analytical electron fluid model has been developed to describe the plasma response to a propagating ion beam. The model predicts very good charge neutralization during quasi-steady-state propagation, provided the beam pulse duration is much longer than the electron plasma period. In the opposite limit, the beam pulse excites large-amplitude plasma waves. Figure 1 shows the influence of a solenoidal magnetic field on charge and current neutralization. Analytical studies show that the solenoidal magnetic field begins to influence the radial electron motion when $\omega_{ce}>\beta\omega_{pe}$. Here, ω_{ce} is the electron gyrofrequency, ω_{pe} is the electron plasma frequency, and $\beta=V_b/c$ is the ion beam velocity. If a solenoidal magnetic field is not applied, plasma waves do not propagate. In contrast, in the presence of a solenoidal magnetic field, whistler waves propagate ahead of the beam and can perturb the plasma ahead of the beam pulse. In the limit $\omega_{ce}>>\beta\omega_{pe}$, the electron current completely neutralizes the ion beam current and the beam self magnetic field greatly diminishes. Application of an external solenoidal magnetic field clearly makes the collective processes of ion beam-plasma interactions rich in physics content. Many results of the PIC simulations remain to be explained by analytical theory. Four new papers have been published or submitted describing plasma neutralization of an intense ion beam pulse. Key references for this work can be found as 2004 PPPL reports at website http://www.pppl.gov/pub_report// — *Igor Kaganovich*

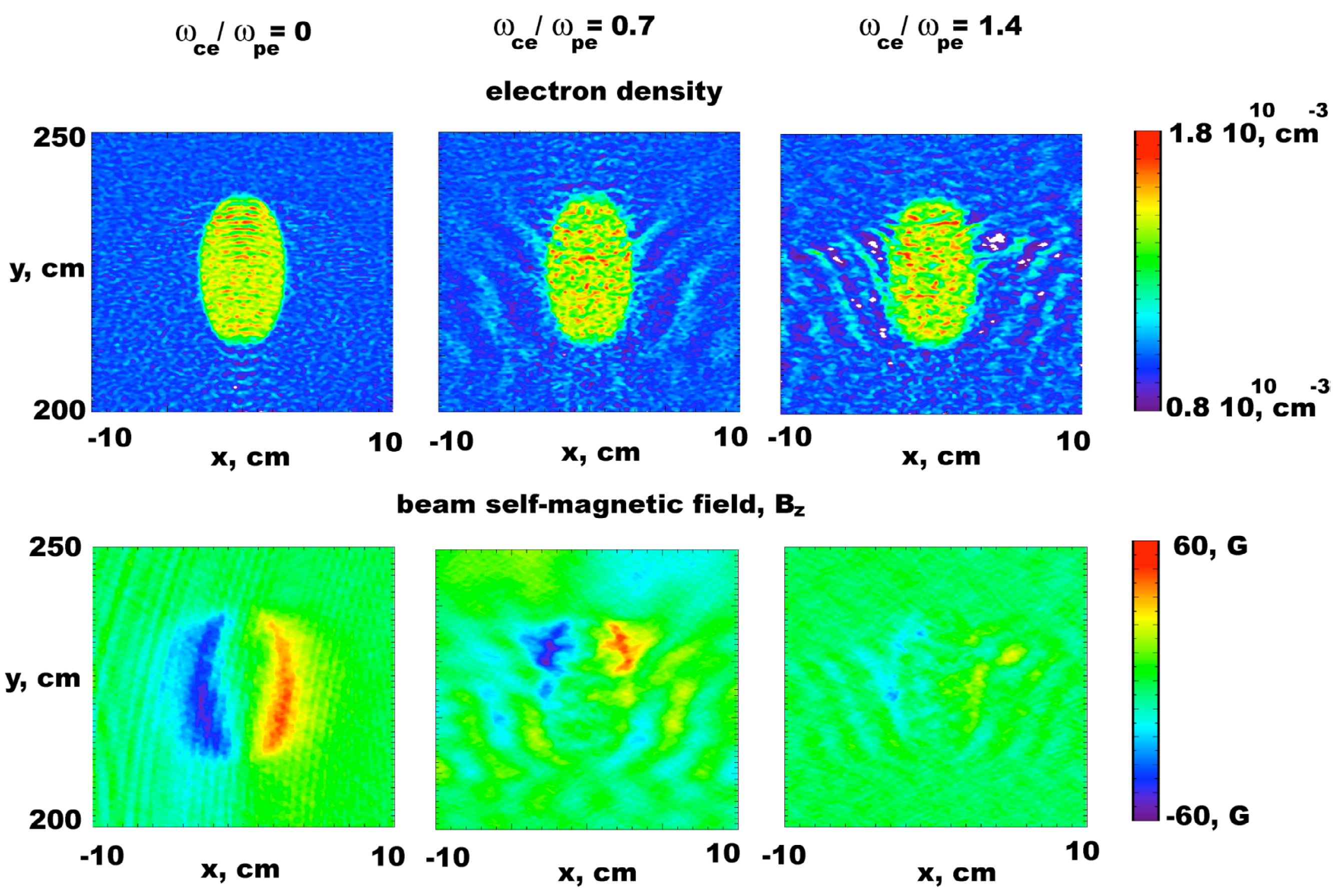

Figure 1. The charge and current neutralization of the ion beam pulse is calculated in two-dimensional slab geometry using the LSP code for various magnetic field strengths corresponding to ω_{ce}/ω_{pe}=0, 0.7, 1.4. Shown in the figure are electron charge density (top) and beam self magnetic field (bottom) contour plots in (x,y) space. The background plasma density is $n_p=10^{11}cm^{-3}$. The beam velocity is $V_b=0.2c$, the beam current 48.0A corresponds to the ion beam density $n_b=0.5n_p$, and the ion beam charge state is equal to unity. The beam dimensions (r_b=2.85cm and τ_b=4.75 ns) correspond to a beam radius $r_b=1.5c/\omega_{pe}$, and pulse duration $\tau_b\omega_{pe}=75$. The solenoidal magnetic field 1014 G corresponds to $\omega_{ce}=\omega_{pe}$.

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